Micro-Resonator Optical Frequency Combs for Photonic Doppler Velocimetry

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Test Readiness and Execution Management
Nevada National Security Site (NNSS)

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Microresonator OFC

- NIF Alpha Heating Experiments: 430 km/s
- Optical Frequency Comb (OFC)
  - Wide spectrum
  - Coherence
- OFC based multifunction PDV
  - System configurations
  - Femtosecond based
- Microresonators
  - MgF2, CaF
  - SiN
  - AlN
  - GaN? AlGaN? AlInGaN?
- Conclusion
  - Microresoantor OFC is a most promising new technology
  - Seeking strong collaborations

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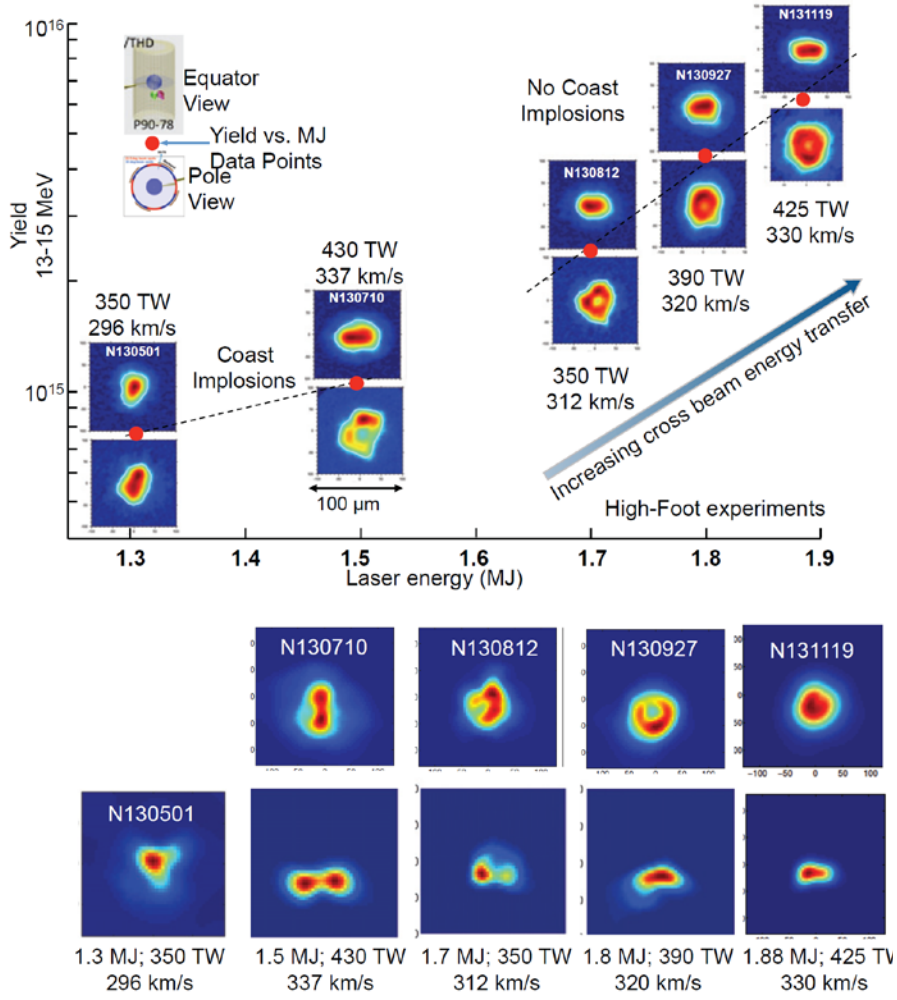
High Velocity NIF Experiments



- NIF Alpha Heating Experiments: 430 km/s
- VISAR
- X-ray Shadowgraphy
- PDV?

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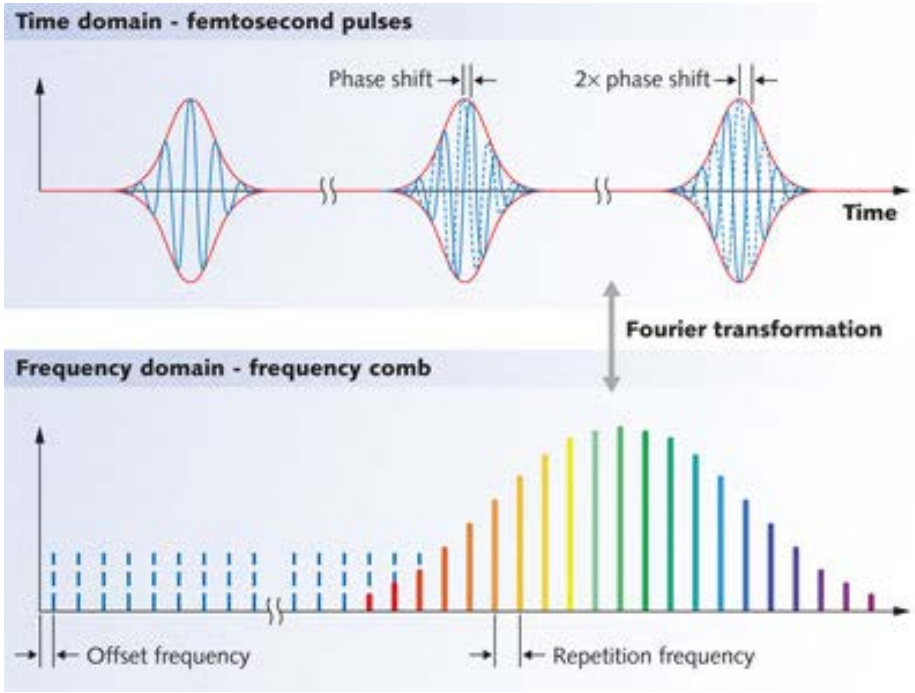
Optical Frequency Comb



- Spectrum
  - Octave range:
    - 400-800 nm
    - 800-1600 nm
  - Adjustable frequency spaing
    - 80 MHz – 10 GHz for conventional configuration
    - 10-100 GHz for microresonator
  - Adjustable repetition rate
- Coherence
  - 1E-20 frequency stability
    - Comparison of atomic clocks for fundamental physics
  - Time-Frequency reference link between optical wave and microwave domains
- John Hall and Ted Hansch
  - Nobel Prize in Physics 2005
  - Revolutionized optical time and frequency metrology
  - Prof. Hall collaborating with UNLV

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Optical Frequency Comb PDV Proposal

Optical Frequency Comb Based Multi-Function Photonic Doppler Velocimetry

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Lawrence Livermore National Lab
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Microresonator Optical Frequency Comb (OFC) R&D Focused Areas

FY17

Kevin Sun August 18, 2016

The Task Order will support explorative research and development of Microresonator Optical Frequency Combs (OFC) and their applications. Microresonator OPC is a new field of research. Our plan is focused in the areas that are mostly relevant to DE&SS missions in SCE, HE tests, and shock physics: microresonator as a foundation of the technology, calibration time base, and ultrahigh dynamic range PDV.

Other cool aspects, such as spectroscopy, hyperspectral imaging, temperature measurement etc., will be pursued in further future phases, and hope to get additional support from other agencies.

1. **Microresonator for Optical Frequency Combs**

We will first learn how to design and fabricate the current version of the microresonators, then explore the design and fabrication new generations, especially with DE&SS applications as a goal: wide temporal and frequency coverage, high calibration precision, wavelength extension

- Collaborative effort with Jet Propulsion Laboratory (JPL) in acquiring a first MgF_2 or SiN microresonator (Phase 1: FY17 Q1)
- Microresonator fabrication at UNLV --- Setting up mounting, grinding and polishing equipment (Phase 2: FY17)
- Design and fab effort for larger microresonator for 10-200 GHz mode spacing (50 ps – 4 ps temporal spacing
- Optical coupling study (Phase 3: FY17-18)

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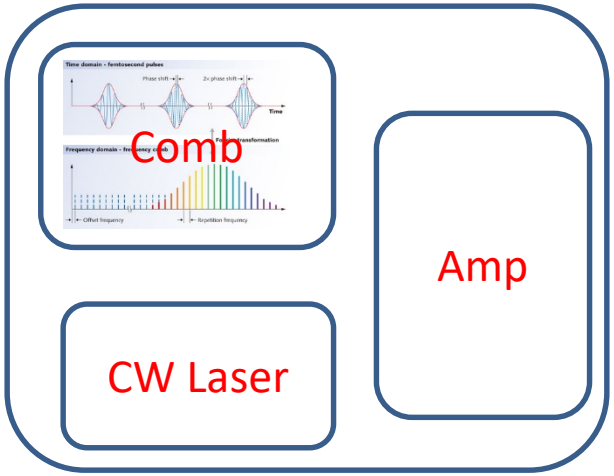
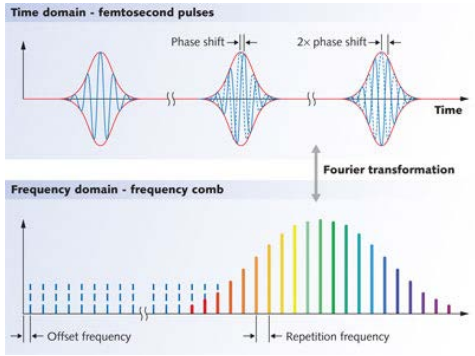
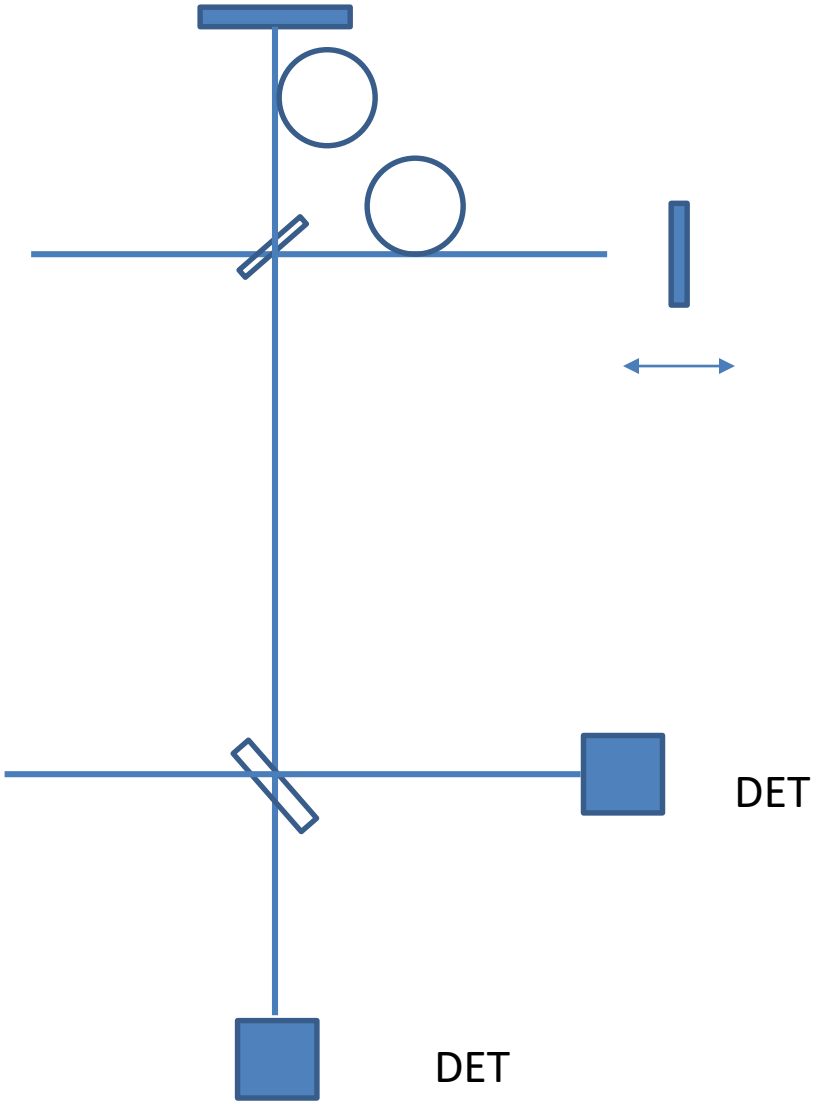
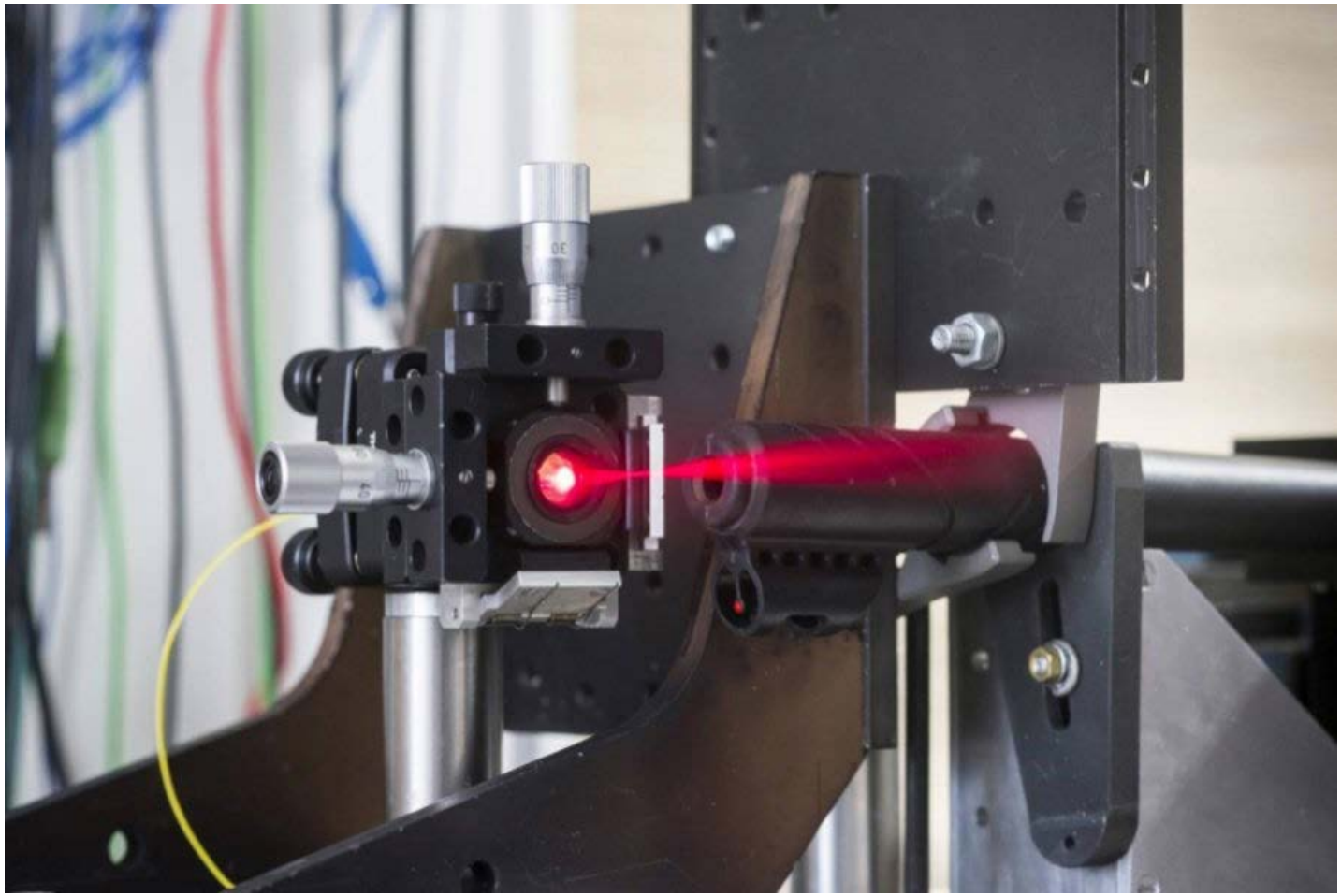
Optical Frequency Comb Based PDV







Recent OFC Experiments by Upcomers



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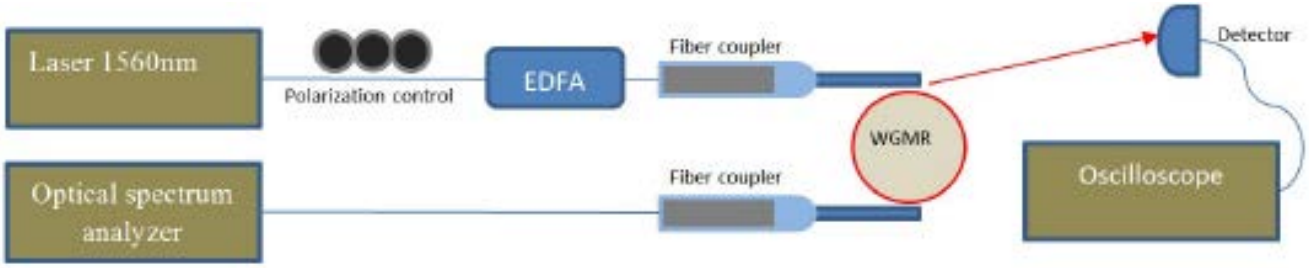
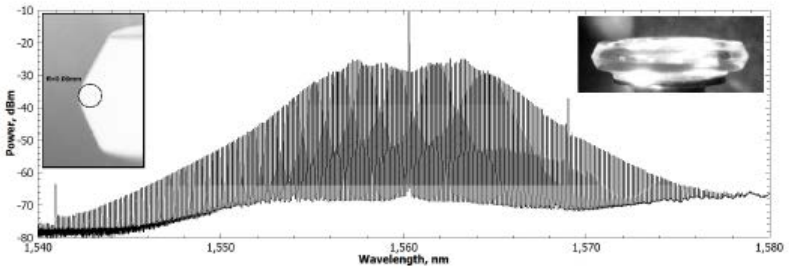
New Optical Combs Using High Q Micro Resonators





- Microresonator
  - 0.4 mm WGM sphere
- Pump
  - 50 mW threshold
  - 1560 nm
- Spectrum
  - Mode spacing 174 GHz
- Coherence
  - Adequate for PDV

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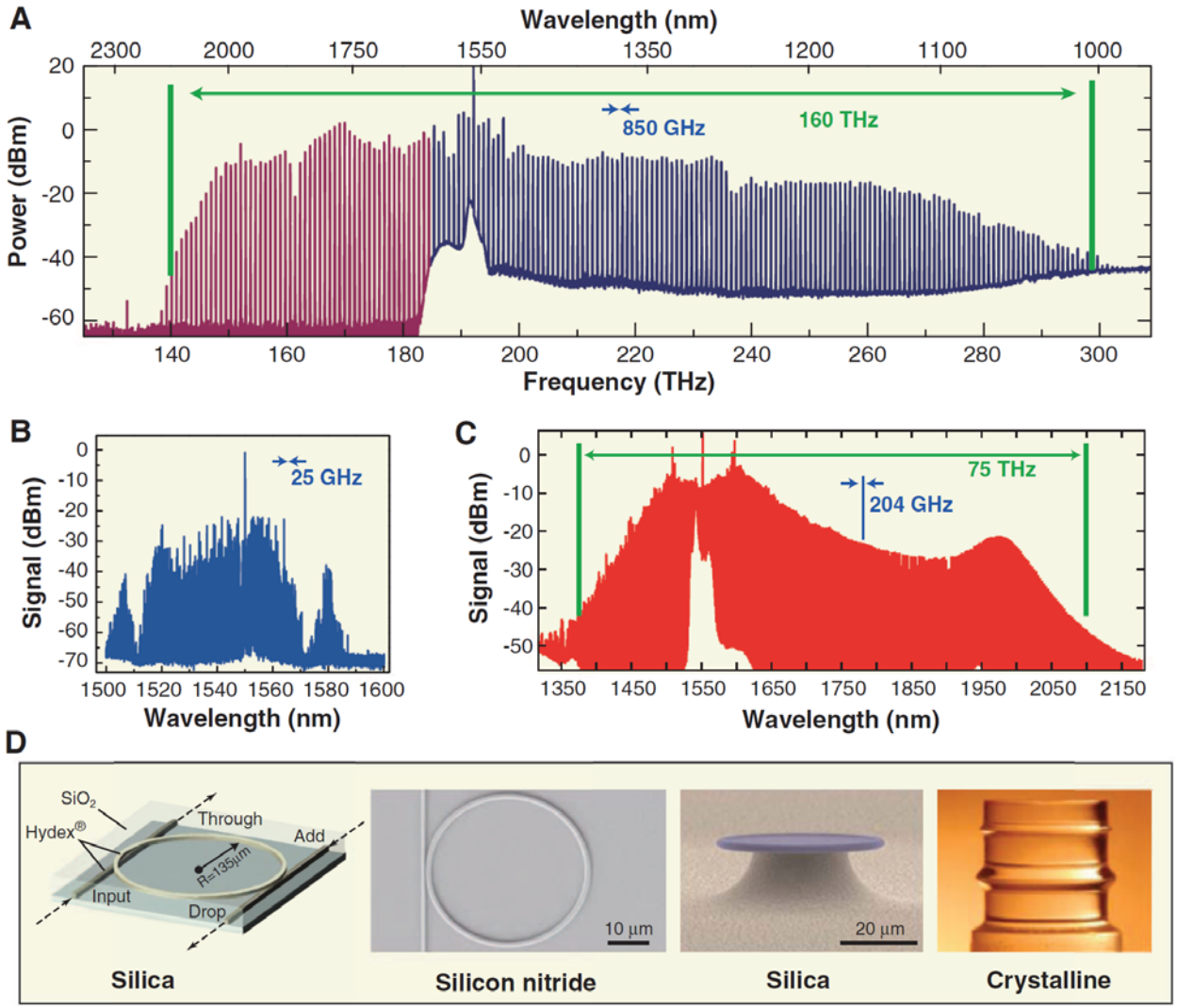
Microresonator OFC



- 1550 nm
- SiO_2
- SiN on SiO_2
- Si Crystals

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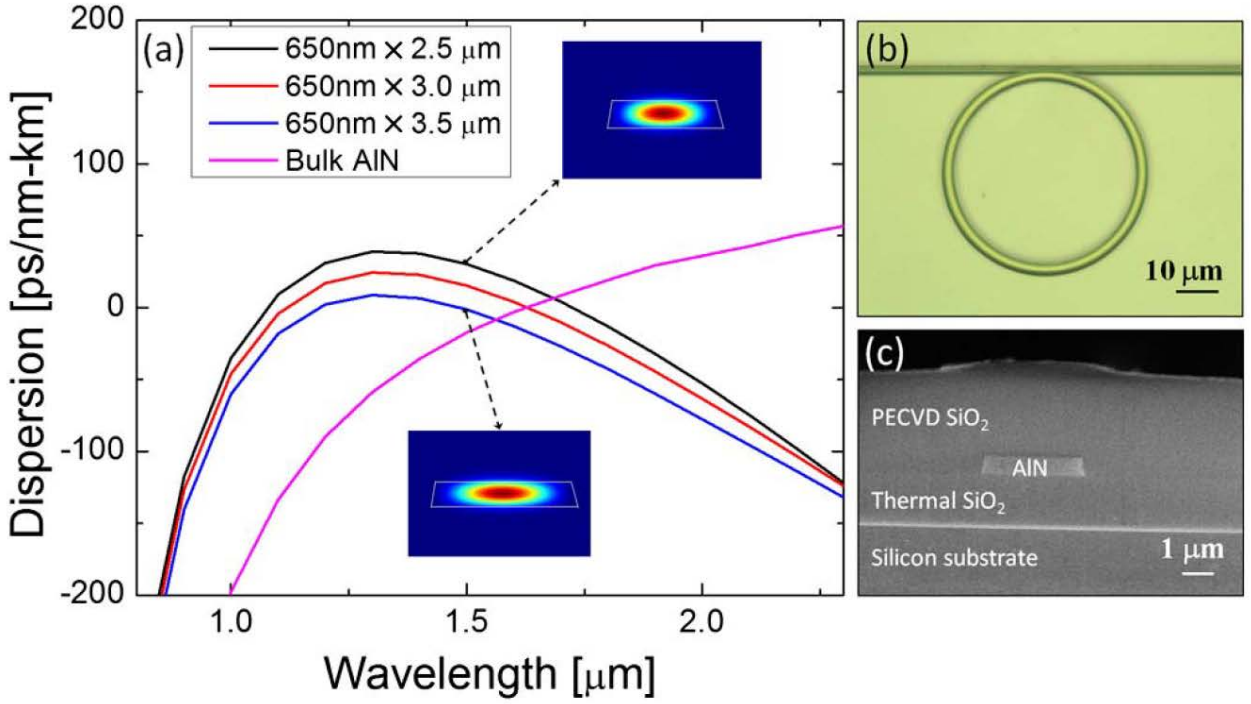
Microresonator OFC: AlN



- 1550 nm
- AlN

Microresonator OFC: GaN?

- 1550 nm transparency
- SHG generation
- THG probe demonstration
- MOCVD fabrication
- Integrated optics?
- Electronics integration?
- AlGaN?

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Outlook

- Optical Frequency Comb Based PDV promissing
- Microresonator OFC is a critical enabling technology
- UNLV team will develop the Microresonator and OFC based PDV technologies
- Proceed collaboratively

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